EXHIBIT 2

UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF TEXAS
WACO DIVISION

<table>
<tr><td>ALIGN TECHNOLOGY, INC.,

Plaintiff,

v.

CLEARCORRECT OPERATING, LLC, CLEARCORRECT HOLDINGS, INC., & INSTITUT STRAUMANN AG,

Defendants.</td><td>Case No. 6:24-cv-00187-ADA-DTG

PATENT CASE

JURY TRIAL DEMANDED</td></tr>
<tr><td>CLEARCORRECT OPERATING, LLC, CLEARCORRECT HOLDINGS, INC., & STRAUMANN USA, LLC,

Counterclaim-Plaintiffs,

v.

ALIGN TECHNOLOGY, INC.,

Counterclaim-Defendant.</td><td></td></tr>
</table>

DECLARATION OF KARAN SINGH, PHD IN SUPPORT OF
ALIGN'S RESPONSIVE CLAIM CONSTRUCTION BRIEF

TABLE OF CONTENTS

1. I have been asked by counsel for Align Technology, Inc. ("Align") to provide opinions regarding how a skilled artisan would have understood certain terms appearing in U.S. Patent No. 8,038,444 as of August 30, 2006. My opinions regarding those claim terms and the knowledge of a skilled artisan are set forth below in this report.

I. BACKGROUND AND QUALIFICATIONS

2. My Curriculum Vitae details my qualifications, experience, honors, patents, presentations, grants, and publications, and is attached as **Appendix A**. Some of my background and experience that qualifies me to offer opinions as an expert on the technical issues in this case are as follows.

3. I hold several Computer Science and Engineering degrees. In 1991, I received my Bachelor of Technology degree in Computer Science and Engineering from the Indian Institute of Technology. I was awarded a Master of Science degree in 1992, and a Ph.D. in 1995, both from Ohio State University and both in Computer and Information Science. My Ph.D. dissertation concerned creating models and representations of digital humans that could interact in graphical environments. I can read and program fluently in various computer programming languages, such as C, C#, C++, Pascal and Java.

4. In 1994, I was invited to conduct research at the Advanced Telecommunications Research laboratory in Kyoto, Japan. During that time, I researched virtual reality technology, specifically designing graphical environments in which human characters could interact with computing systems.

5. Between 1995 and 1999, I worked at Alias|Wavefront in Toronto, Canada. My responsibilities included designing character animation and facial modeling tools for the first release of Maya, a software system for computer graphical modeling, animation, and rendering.

The software won a technical Oscar in 2003 and is still the premiere software package used for these functions today.

6. I have worked with Chris Landreth, a director of animated films, since I started with Alias|Wavefront in 1995. Chris and I worked together on the design of Maya and have subsequently worked on a number of film projects. Notable among these projects is the short film "Ryan," for which I was the Software R+D Director, which won an Oscar for Best Animated Short in 2005.

7. Later in 1999, I joined a start-up company in California called Paraform Inc. My work involved developing a system that transformed 3D scanned data from real objects into useable digital models for a variety of downstream applications.

8. Also in 1999, I was a Visiting Professor of Computer Science at the University of Otago in New Zealand. During that time, I taught and conducted research in computer graphics.

9. Since 2002, I have been a Professor of Computer Science at the University of Toronto where I co-direct a graphics and human computer interaction laboratory dgp (dynamic graphics project), conduct research and teach classes in computer science, graphics, and in human computer interaction.

10. During this period, I have also undertaken technical consulting projects with various companies in the information technology, graphics, animation and design space, including most recently Weta Digital in New Zealand, where I worked on the creation of a facial animation system for the film "Avatar: The Way of Water," which won an Oscar for Best Visual Effects in 2023.

11. I have supervised research that has been successfully commercialized including MeshMixer, a software for 3D object modeling and fabrication (acquired by Autodesk in 2011). I

have also co-founded multiple companies including conceptualiz (software that processes and manipulates medical imaging data for surgical planning), and JALI Research (facial animation). JALI has been used to animate the speech for characters in several high-profile, high-production-value video games like “Cyberpunk 2077”.

12. My research interests lie in interactive graphics, spanning geometric and anatomic modeling, visual perception, character and facial animation, sketch/touch based interfaces and interaction techniques for Augmented Reality and Virtual Reality (AR/VR).

13. I have authored or co-authored over 150 peer-reviewed publications on a variety of topics in computer science. I am an inventor on several U.S. patents related to topics in human computer interaction and computer graphics. I have a number of publications pertaining to 3D digital scanning, anatomic modelling, transformation and animation, as well as their application to biomechanics and biomedical engineering, including the following representative articles and communications:

- *Feature based retargeting of parameterised geometry* IEEE Geometric Modeling & Processing (2004);
- *Anatomic rigging of characters from the outside-in*. ACM SIGGRAPH/EG SCA (2005);
- *Helping Hand: An Anatomically Accurate Inverse Dynamics Solution For Unconstrained Hand Motion* – ACM SIGGRAPH/EG SCA (2005);
- *Computational representation of the aponeuroses as NURBS surfaces in 3D musculoskeletal models*. Computer Methods and Programs in Biomedicine (2007);
- *Three-dimensional muscle model of mandibular elevation and depression based on digitized data from cadaveric specimens*. American Society of Biomechanics

Meeting (2007);

- *Extracting lines of curvature from noisy point clouds* – Computer-Aided Design, (2009);
- *Multi-objective shape segmentation and labeling* – Computer Graphics Forum (2009);
- *Determining physiological cross-sectional area of extensor carpi radialis longus and brevis as a whole and by regions using 3D computer muscle models created from digitized fiber bundle data* (Computer Methods and Programs in Biomedicine (2009));
- *Fiber bundle element method of determining physiological cross sectional area from three-dimensional computer muscle models created from digitized fiber bundle data* – Computer Methods in Biomechanics and Biomedical Engineering (2010),
- *meshmixer: an interface for rapid mesh composition*. ACM SIGGRAPH (2010);
- *High-Precision Surface Reconstruction of Human Bones from Point-Sampled Data*. International Summit on Human Simulation (2011);
- *JALI: An Animator-Centric Viseme Model for Expressive Lip-Synchronization* – ACM Transactions on Graphics (2016),
- *Animatomy: an Animator-centric, Anatomically Inspired System for 3D Facial Modeling, Animation and Transfer.* ACM Transactions on Graphics (2022).

14. To the best of my recollection, I have testified as an expert in the following cases in depositions or at trial during the previous four years: *3Shape A/S v. Align Tech*, No. 18-cv-886-

LPS (D. Del.), *Align Tech v. 3Shape A/S*, No. 17-1647-LPS (D. Del.), and *Maxell v. Samsung*, No. 23-cv-00092-RWS (E.D. Tex.).

II. COMPENSATION

15. I am being compensated for my work in connection with this matter at my current standard rate of $700 per hour. I am being separately reimbursed for any out-of-pocket expenses. My compensation does not depend on the outcome of this litigation or the nature of my opinions.

III. LEGAL PRINCIPLES

16. I am not a legal expert and I offer no legal opinions. I have, however, been informed by counsel of various legal standards that are relevant to the issues that I discuss in this declaration. My understanding of those legal standards is set forth below.

A. Critical Date

17. I understand that patent claims are construed according to their meaning as of their critical date(s). I have been asked to assume that the critical date for the ’444 patent’s claims is August 30, 2006. My opinions set forth herein reflect that assumption.

B. General Principles of Claim Construction

18. I understand that patent claims are construed from the perspective of a person of ordinary skill in the art (“skilled artisan”) as of each claim’s critical date. I understand that, in construing claims of a patent, one should first consider the “intrinsic evidence,” which includes the patent’s claim language, its specification, and its prosecution history. I understand that one first considers the words of the claims themselves, giving those words their ordinary and customary meaning to one of ordinary skill in the art as of their critical date. I understand that one next considers the patent specification and evaluates how the specification uses the claim terms, including whether the specification uses any terms or words in a manner inconsistent with their

plain and ordinary meaning. I understand that one also should consider the prosecution history, which is the complete record of all proceedings before the United States Patent and Trademark Office regarding the patent at issue. Statements made by a patentee during prosecution may inform how a skilled artisan would interpret the issued claims.

19. If the intrinsic evidence is not conclusive, I understand that one may consider extrinsic evidence, such as textbooks, expert testimony, and other materials to determine how a skilled artisan would have understood the claims.

C. Indefiniteness

20. I understand that issued patent claims are presumed valid. I understand that, to overcome that presumption, a challenger must prove invalidity by clear and convincing evidence.

21. I understand that, although patent claims are presumed valid, courts may find patent claims invalid as indefinite if a patent challenger proves by clear and convincing evidence that a skilled artisan would not understand what is claimed with reasonable certainty. I understand that a patentee need not define their claims with absolute or mathematical precision for those claims to survive an indefiniteness challenge.

D. Construing Means-Plus-Function Claims

22. I understand that patentees may claim their inventions in functional terms. I understand that, when a patentee takes this approach, the resulting claims are called "means-plus-function" claims. I understand that Section 112(f) of the Patent Act permits such claims:

> An element in a claim for a combination may be expressed as a means or step for performing a specified function without the recital of structure, material, or acts in support thereof, and such claim shall be construed to cover the corresponding structure, material, or acts described in the specification and equivalents thereof.

35 U.S.C. § 112(f).

23. I understand that construing means-plus-function claims requires determining both the claimed function and what structure corresponds to the claimed function. I understand that, if a skilled artisan would not have recognized from a patent's specification which structure corresponds to a claimed function, the corresponding means-plus-function claim is indefinite.

24. I understand that a structure qualifies as a "corresponding" structure if the intrinsic evidence clearly links or associates that structure to the function recited in the claim. I understand that, to qualify as corresponding structure, the structure must be adequate to achieve the claimed function. I also understand, however, that a specification need not disclose details of structures well known in the art. In other words, although a specification generally must disclose *some* structure corresponding to each claimed function, it need not provide an unending disclosure of what everyone in the field knows.

25. I understand that, when a claimed function is performed by software, the specification must, in most cases, disclose an algorithm for performing the claimed function. I understand that the specification need not disclose all the details of an algorithm so long as what is disclosed would be sufficiently definite to a skilled artisan. I further understand that a specification need not describe an algorithm if the selection of the algorithm or group of algorithms needed to perform the claimed function in question would be readily apparent to a skilled artisan.

26. I understand that a specification does not always need to disclose an algorithm corresponding to a claimed function in the context of computer-implemented means-plus-function claims. I understand that, when a function can be achieved by a general-purpose computer without any special programming, the specification need not disclose any more structure than a general-purpose processor that performs the function.

IV. THE ’444 PATENT

A. Overview

27. The ’444 patent is titled “Automatic Treatment Staging for Teeth.” The ’444 patent relates to methods (called “treatment planning”) for determining how and when a patient’s teeth should move during treatment with clear aligners. For example, the ’444 patent’s abstract states:

> Apparatus, system, and methods for utilizing one or more computing devices to stage the movement of teeth during an alignment treatment are disclosed. The computing device receives an electronic representation of the patient's teeth in their initial position and an electronic representation of the teeth a final position for each tooth. A route each tooth will travel to reach its final position is determined, and the teeth are scheduled to move according to a movement pattern. Moreover, the schedule of movement takes into account a maximum rate of tooth movement for each tooth, the path of movement for each tooth, the distance each tooth needs to move, any needed tooth staggering, any needed round-tripping or tooth movement slowing. The invention also includes techniques for determining an optimum number of stages for the treatment based on the schedule of movement.

’444 pat., Abstract.

28. The ’444 patent includes disclosures of computer-implemented treatment planning methods. For example, the ’444 patent describes a computer receiving “an electronic representation of a patient’s teeth in an initial position,” receiving or generating “an electronic representation of a desired final position for each of the patient’s teeth,” and then “automatically creat[ing] a route for each tooth to move from its initial position to its final position.” ’444 pat., 5:12-22. The computer also can be configured to select a “pattern for treatment,” where each “pattern” influences when each tooth moves during treatment. ’444 pat., 6:17-19; *see also* ’444 pat., 2:37-3:4, Figs. 3-10B. The computer also can perform collision avoidance, including so-called “staggering,” “round-tripping,” and “slowing.” ’444 pat., 6:39-46. The ’444 patent describes how to perform those collision-avoidance methods at column 12, lines 41-65.

B. Level of Skill of a Person of Ordinary Skill in the Art

29. In my opinion, a skilled artisan as of August 30, 2006, would have had the knowledge and experience of a collaborative team of skilled artisans including an individual with expertise in software and a qualified orthodontist or other dental practitioner. In my opinion, that collaborative team would have included someone with expertise in software because the ’444 patent generally relates to software for modeling the movement of virtual objects in 3-D space while avoiding collisions between those objects. In my opinion, that collaborative team also would have included someone with expertise in orthodontics because the ’444 patent describes deploying such software methods in the context of digital dentistry. In my opinion, the individual with expertise in software would have had a B.S. in computer science or a similar field and at least two years of work experience as a software engineer or in a similar role or equivalent academic training. I am familiar with the capabilities of such an individual because I hold degrees in computer science and engineering and have worked as a software engineer. In assessing how a skilled artisan would have understood the ’444 patent’s disclosure of various software algorithms, I have considered the intrinsic evidence from the perspective of the foregoing individual with expertise in software.

30. I have reviewed Dr. Xiong’s expert report and I do not see any discussion of the qualifications that a skilled artisan would have had as of August 30, 2006.

C. Disputed Claim Terms

31. I have been asked to opine regarding how a skilled artisan would have interpreted ten claim terms from the ’444 patent’s claims. For the purposes of this declaration, I have been asked to assume that each term is a so-called “means-plus-function” term. I understand that the

parties do not dispute the corresponding function for each term. I understand that the parties do dispute, however, whether the ’444 patent discloses adequate corresponding structure.

32. I set forth my opinions regarding whether the specification discloses adequate corresponding structure for each disputed term below. I have also, where appropriate, addressed specific criticisms raised by Dr. Xiong, who I understand offers testimony in support of ClearCorrect’s claim construction positions. In the interest of efficiency, I have focused on explaining why I disagree with Dr. Xiong’s ultimate conclusions rather explaining why I disagree every single one of his individual assertions. The fact that I do not discuss any particular assertion by Dr. Xiong does not, however, mean that I agree with it.

1. “means for receiving an electronic representation of each dental object of the plurality of dental objects in relation to one another” (’444 patent cls. 15-28)

Align’s Construction	Defendants’ Construction
a computing device and equivalents E.g., ’444 patent, 5:12-16	Subject to § 112 ¶ 6 • <u>Function:</u> receiving an electronic representation of each dental object of the plurality of dental objects in relation to one another • <u>Structure:</u> None Indefinite

33. I understand that the parties agree that the function corresponding to this term is “receiving an electronic representation of each dental object of the plurality of dental objects in relation to one another.” I also understand that Align has identified “a computing device and equivalents” as the structure that corresponds to this function.

34. In my opinion, “a computing device and equivalents,” *i.e.*, a general-purpose computer having a processor, corresponds to the claimed function. Receiving “an electronic

representation of each dental object of the plurality of dental objects in relation to one another" refers to receiving a virtual/digital model of a patient's dentition. A skilled artisan would have recognized that such a virtual model is digital data stored in computer memory and, thus, that a general-purpose computer could receive it (for example, as a digital file from an external drive, or as a stream of digital data sent across a network from another computing device). Consistent with my opinion, the '444 patent states that "a computing device is configured to receive an electronic representation of a patient's teeth in an initial position." '444 pat., 5:12-14.

35. I understand that Dr. Xiong contends that the '444 patent does not disclose adequate corresponding structure because it does not, according to Dr. Xiong, recite "any software algorithm or any other guidance or particular method by which the computing device is to be configured to receive an electronic representation of the patient's teeth." Xiong Decl., ¶ 44. In other words, Dr. Xiong apparently contends that a general-purpose computer could not, by default, receive the virtual model of a patient's teeth.

36. I disagree with Dr. Xiong. A general-purpose computer would not need to be specially configured before it could receive digital data comprising "an electronic representation of each dental object of the plurality of dental objects in relation to one another." General-purpose computers typically include several kinds of hardware for receiving data, including USB ports and WiFi chips. A skilled artisan would have recognized that a general-purpose computer corresponded to the claimed function.

37. I also disagree with Dr. Xiong's statement that the '444 patent's specification at column 5, lines 12-16 does not disclose "the plurality of dental objects *in relation to one another*." Xiong Decl., ¶ 44 (emphasis added). That passage refers to "an electronic representation of a patient's teeth in an initial position" and, as the '444 patent indicates, "initial position" refers to an

electronic representation of each dental object of the plurality of dental objects in relation to one another. ’444 pat., 5:12-16. For instance, the ’444 patent’s specification graphically illustrates a top-view of teeth in relation to one another in its Figure 1A (shown below) and describes that figure as “illustrat[ing] the initial positions of the patient’s teeth.” ’444 pat., 3:37-38.

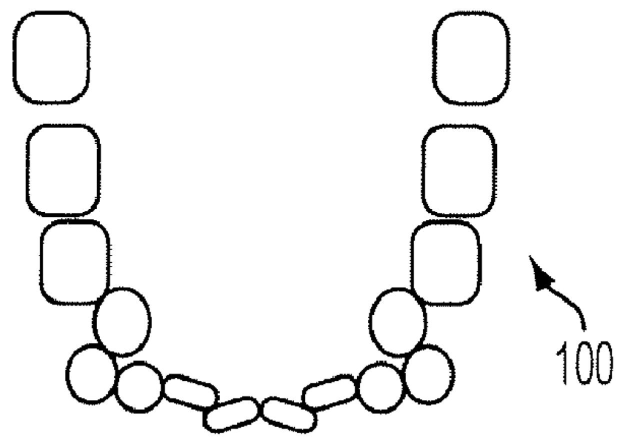

FIG. 1A

’444 pat., Fig. 1A. In other words, a skilled artisan would have understood that an electronic representation of a patient’s teeth in an initial position referred to a digital model of a patient’s dentition, which necessarily would depict a plurality of teeth in relation to one another. Thus, the passage that Dr. Xiong cites does disclose the plurality of dental objects in relation to one another.

2. “means for determining an order of movement for each respective dental object such that the dental objects avoid colliding with each other on their respective routes from said initial position to said desired final position” (’444 patent cls. 15-28)

Align’s Construction	Defendants’ Construction
a computer program that performs the steps identified in Figure 2B and equivalents E.g., ’444 patent, 5:19-22, 5:29-6:46, Fig. 2B	Subject to § 112 ¶ 6 • Function: determining an order of movement for each respective dental object such that the dental objects avoid colliding with each other on

	their respective routes from said initial position to said desired final position. • Structure: None Indefinite

38. I understand that the parties agree that the function corresponding to this term is "determining an order of movement for each respective dental object such that the dental objects avoid colliding with each other on their respective routes from said initial position to said desired final position." I also understand that Align has identified "a computer program that performs the steps identified in Figure 2B and equivalents" as the structure that corresponds to this function. Figure 2B is reproduced below:

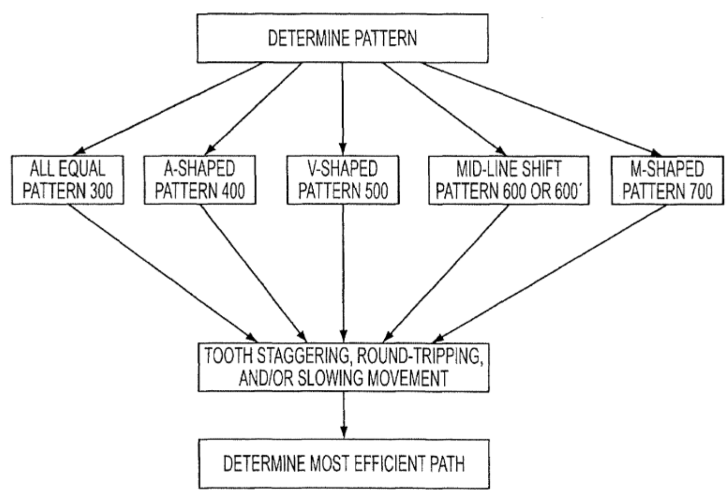

FIG. 2B

'444 pat., Fig. 2B.

39. In my opinion, "a computer program that performs the steps identified in Figure 2B and equivalents" corresponds to the claimed function. A skilled artisan would have recognized that Figure 2B discloses an algorithm performing (and thus corresponding to) the claimed function

via three steps: (1) "determine pattern"; (2) determine the "tooth staggering, round-tripping, and/or slowing movement" to be performed; and (3) "determine most efficient path." '444 pat. Fig. 2B.

40. In my opinion, the first step in Figure 2B's algorithm contributes to performing the claimed function. According to the '444 patent, the patterns recited in Figure 2B (all equal, A-shaped, V-shaped, mid-line shift, M-shaped) influence the order in which a patient's teeth move. For instance, Figure 3, which the specification identifies an example of an "all-equal" pattern depicts all a patient's teeth moving at once. *See* '444 pat., Fig. 3, 2:37-39. Similarly, Figure 4, which the specification identifies as an example of an "A-shaped" pattern, depicts some teeth moving at stage 0 with others moving later. *See* '444 pat., Fig. 4, 2:40-42. Thus, the step of determining a pattern impacts the order of movement for each respective dental object.

41. In my opinion, the second step in Figure 2B's algorithm—staggering, round-tripping, and/or slowing—also contributes to performing the claimed function. The '444 patent defines "staggering" as "delaying one or more teeth from moving one or more stages where it would otherwise move in order to prevent another tooth from colliding with and/or obstructing the path of the delayed tooth." '444 pat., 12:44-48. Thus, staggering alters the order of movement by delaying when a tooth begins moving. Next, the '444 patent defines "round-tripping" as "the technique of moving a first tooth out of the path of a second tooth, and once the second tooth has moved sufficiently, moving the first tooth back to its previous position before proceeding to a desired final position of that first tooth." '444 pat., 12:51-55. Because "round-tripping" involves moving a tooth back to its initial position only after another tooth passes it by, "round-tripping" alters the order of movement. Finally, the '444 patent defines "slowing" as "the process of having one or more teeth scheduled to move at a rate less than the rate of other teeth, or even stopping using interim key frames, so that collisions and/or obstructions do not occur." '444 pat., 12:41-

55. Slowing alters the order of movement because a slowed tooth will move for more stages than it would have moved had it moved at its original rate. Thus, each technique alters the order of movement in the interest of avoiding collisions.

42. In my opinion, the third and final step in Figure 2B's algorithm, which is "determine most efficient path," also contributes to performing the claimed function. Determining the most efficient path for each tooth accounts for collisions because, otherwise, each tooth could not proceed from its initial to final position along that path. *See also* '444 pat., 3:51-57 (explaining that software "accounts for any collisions that might occur between teeth" when "calculat[ing] one or more of the intermediate positions"). Thus, this step also contributes to collision avoidance. In short, a skilled artisan would have recognized that Figure 2B's three steps accomplish the claimed function and thus correspond to it.

43. I understand that Dr. Xiong contends that the '444 patent does not provide adequate structure corresponding to the claimed function. Xiong Decl., ¶¶ 52-67. Based on my review of Dr. Xiong's declaration, it appears that Dr. Xiong's analysis focuses on whether each isolated disclosure cited by Align provides adequate supporting structure for the corresponding structure for the claimed function. Xiong Decl., ¶¶ 52-66. The only opinion that Dr. Xiong offers regarding the cited disclosures as a whole is the following sentence: "Nor does reading these portions of the specification together provide sufficient structure for performing the claimed functions." Xiong Decl., ¶ 67. At a fundamental level, I disagree with Dr. Xiong's approach: in my opinion, a skilled artisan would have read the '444 patent as a whole.

44. I also disagree with Dr. Xiong's criticisms of the individual disclosures that Align identified as the corresponding structure. For instance, Dr. Xiong contends that Figure 2B does not correspond to the claimed function because it "does not even mention collision avoidance and

provides no algorithm for how that claimed function is performed" and because it "provides no guidance at all on how to determine what constitutes the most efficient path" nor "how one is supposed to combine picking a pattern term with one or more 'movement[s].'" Xiong Decl., ¶¶ 65-66. As I have already explained, however, performing Figure 2B's steps does result in collision avoidance and Figure 2B discloses the steps for how that function is performed.

45. I also understand that Dr. Xiong contends the prose appearing at column 5, lines 19-22 and at column 5, line 29 to column 6, line 46 of the specification does not adequately disclose an algorithm corresponding to the claimed function. Xiong Decl., ¶¶ 52-63. I disagree with Dr. Xiong. These passages recite further detail regarding the steps disclosed in Figure 2B's algorithm. For example, they convey how to determine which pattern to use, '444 pat., 5:41-60, they refer a reader to later descriptions of how to perform "staggering," "round-tripping," and "slowing" and in what order to do so, '444 pat., 6:39-41, 12:41-55, and they indicate that a "program stored within the computing device is configured to analyze the initial and final positions, and automatically create a route for each tooth to move from its initial position to its final position," '444 pat., 5:19-22. In short, beyond describing Figure 2B's algorithm in prose, these passages would have helped a skilled artisan interpret Figure 2B's algorithm.

3. "means for determining a route each respective dental object will move to achieve its respective final position" ('444 patent cls. 16-18)

Align's Construction	Defendants' Construction
a computer program that is configured to segment an initial digital dataset into digital models of individual dental objects and gingival tissue, calculate a transformation for each dental object, and then calculate one or more intermediate positions for each dental object, taking into account any constraints imposed on the movement of dental objects and any collisions that might occur between dental objects as the dental objects move	Subject to § 112 ¶ 6 • Function: determining a route each respective dental object will move to achieve its respective final position • Structure: None Indefinite

from one treatment stage to the next and equivalents E.g., '444 patent, 3:19-24, 3:36-61	

46. I understand that the parties agree that the function corresponding to this term is "determining a route each respective dental object will move to achieve its respective final position." I also understand that Align has identified "a computer program that is configured to segment an initial digital dataset into digital models of individual dental objects and gingival tissue, calculate a transformation for each dental object, and then calculate one or more intermediate positions for each dental object, taking into account any constraints imposed on the movement of dental objects and any collisions that might occur between dental objects as the dental objects move from one treatment stage to the next and equivalents" as the structure that corresponds to this function.

47. In my opinion, the algorithm recited in Align's construction corresponds to the claimed function. A skilled artisan reading the '444 patent would have recognized that the first step in determining a route is segmentation. The '444 patent states that "[a] digital model of [a patient's] teeth at [their] initial positions is captured in an initial digital data set (IDDS)." '444 pat., 3:39-40. It goes on explain how a computer program processes that IDDS in the context of preparing a treatment plan: "A computer program segments the IDDS into digital models of individual teeth and the gingival tissue." '444 pat., 3:42-43. Segmenting the model into individual teeth facilitates the later steps discussed below.

48. A skilled artisan reading the '444 patent would have recognized that the second step in determining a route is computing transformations from the teeth's initial positions to their

final positions.[1] When discussing "computer-implemented techniques for using the digital models in designing and simulating an orthodontic treatment plan for the patient," the '444 patent discloses that one such technique involves "receiving an initial data set that represents the patient's teeth before treatment, specifying a desired arrangement of the patient's teeth after treatment, and calculating transformations that will move the teeth from the initial to the final positions over desired treatment paths." '444 pat., 3:16-24. The term "transformation" was commonly understood to refer to a change in position and/or orientation of an object. Thus, a skilled artisan would understand that "calculating transformations" refers to computing the change in position and/or orientation necessary to achieve a final position. Because the program computes a transformation for each individual tooth, this step occurs after segmentation.

49. A skilled artisan reading the '444 patent would have recognized that the third step in determining a route is calculating one or more intermediate positions for each dental object, taking into account any constraints imposed on the movement of dental objects and any collisions that might occur between dental objects as the dental objects move from one treatment stage to the next and equivalents. The '444 patent states that, after "[a] human operator and/or a computer program manipulate the digital models of the patient's teeth to achieve the final tooth positions," *i.e.*, after determining a net transformation for each tooth, "[t]he program then calculates one or more intermediate positions." '444 pat., 3:51-52. According to the '444 patent, calculating those intermediate positions includes "taking into account any constraints imposed on the movement of

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[1] Computing these transformations also requires knowing the desired final positions of the patient's teeth. In the scenario in which a computer generates the final tooth positions, '444 pat., 3:49-52, this algorithm would include the additional step of manipulating the segmented virtual model to achieve final tooth positions. Because the '444 patent discloses that a human operator can provide the final positions of the patient's teeth, however, a skilled artisan would have recognized that it was not necessary for the software algorithm to perform the step of defining the final positions of a patient's teeth. *See* '444 pat., 3:48-51.

the teeth by the human operator or by the natural characteristics of the teeth themselves," *e.g.*, keeping the teeth within the boundaries defined by the gingival tissue, and "for any collisions that might occur between teeth as the teeth move from one treatment stage to the next." '444 pat., 3:48-56. A skilled artisan reading the '444 patent would recognize that, by computing the intermediate positions for each tooth, the program defines a route each tooth takes to achieve its respective final position. Thus, a skilled artisan would have recognized that the combination of the three foregoing steps adequately corresponds to the claimed function.

50. I understand that Dr. Xiong contends the '444 patent does not disclose sufficient structure corresponding to this algorithm. Dr. Xiong's objection appears to be that the specification does not disclose sufficient corresponding structure because, in his opinion, the algorithm does not state how the route is computed for each tooth at a level of granularity preferred by ClearCorrect. Xiong Decl., ¶¶ 69-78. I disagree with Dr. Xiong's conclusion because, as I have already explained, a skilled artisan would have recognized that practicing the claimed function required: (1) segmenting an IDDS; (2) computing transformations; and (3) determining intermediate states while accounting for constraints and collisions.

4. "means for determining (a), (b), and (c) in relation to each of the other dental objects" ('444 patent cls. 17-18)

Align's Construction	Defendants' Construction
a computer program that is configured to segment an initial digital dataset into digital models of individual dental objects and gingival tissue, calculate a transformation for each dental object, and then calculate one or more intermediate positions for each dental object, taking into account any constraints imposed on the movement of dental objects and any collisions that might occur between dental objects as the dental objects move from one treatment stage to the next and equivalents	Subject to § 112 ¶ 6 • <u>Function</u>: determining (a), (b), and (c) in relation to each of the other dental objects • <u>Structure</u>: None Indefinite

E.g., ’444 patent, 3:19-24, 3:36-61	

51. I understand that the parties agree that the function corresponding to this term is “determining (a), (b), and (c) in relation to each of the other dental objects.” I also understand that Align has identified “a computer program that is configured to segment an initial digital dataset into digital models of individual dental objects and gingival tissue, calculate a transformation for each dental object, and then calculate one or more intermediate positions for each dental object, taking into account any constraints imposed on the movement of dental objects and any collisions that might occur between dental objects as the dental objects move from one treatment stage to the next and equivalents” as the structure that corresponds to this function.

52. From my review of the claims, I understand that “(a), (b), and (c),” in this claim term from claim 17 refer to the bullets (a), (b), and (c), recited in the preceding claim 16. I have reproduced those bullets from claim 16 below:

> (a) means for determining a route each respective dental object will move to achieve its respective final position;
> (b) means for determining the distance each respective dental object will move to achieve its respective final position; and
> (c) means for determining a rate at which each respective dental object will move along its respective route.

’444 pat., cl. 16. Thus, reading claims 16 and 17 together, claim 17 requires a means for determining each of the foregoing functions for each tooth in relation to the other teeth.

53. In my opinion, the ’444 patent adequately identifies to a skilled artisan what structures correspond to these claimed functions. As I explain in paragraphs 46-50 of this report, the algorithm recited in Align’s construction adequately corresponds to the step of “determining a route . . . .” That determination of routes for each tooth is done “in relation to each of the other dental objects” because, for instance, it accounts for collisions with other dental objects.

54. For the same reasons that I express below in paragraphs 56-64 of my report, the ’444 patent also adequately conveys to a skilled artisan how to practice the functions of “determining a distance . . .” and “determining a rate . . .” for each tooth. Those determinations also are done “in relation to each of the other dental objects.” For instance, as I explain below, the distance determination sums individual distances travelled. *Infra* ¶¶ 62-64. Because teeth must sometimes depart from a straight-line path from their initial to their final position to avoid colliding with other teeth, *see e.g.*, ’444 pat., 12:51-55 (describing round-tripping), the total distance traveled by any one tooth reflects the influence of, and therefore is determined in relation to, the other teeth. Similarly, the rate for each tooth depends on the number of stages that tooth must travel to achieve each tooth’s final position, *infra* ¶¶ 56-61, and, since the other teeth can influence the number of stages required, the determination of rate also is in relation to the other teeth. *See, e.g.*, ’444 pat., 12:48-51 (describing slowing).

55. I understand that Dr. Xiong contends that the specification does not disclose adequate corresponding structure for this claim term. Xiong Decl., ¶¶ 95-105. The heart of Dr. Xiong’s objection appears to be, again, that the disclosed structure does not explain how to perform the claimed function at a level of granularity preferred by ClearCorrect. *See* Xiong Dec., ¶¶ 99, 102-104. Once again, I disagree with Dr. Xiong because, as I have explained, the specification adequately indicates to a skilled artisan what algorithms correspond to the claimed functions.

5. “means for determining a rate at which each respective dental object will move along its respective route” (’444 patent cls. 16-18)

Align’s Construction	Defendants’ Construction
a computer program that determines a rate at which each respective dental object will move along its respective route E.g., ’444 patent, 4:58-5:10	Subject to § 112 ¶ 6 • <u>Function</u>: determining a rate at which each respective dental object will move along its respective route

	• Structure: None Indefinite

56. I understand that the parties agree that the function corresponding to this term is "determining a rate at which each respective dental object will move along its respective route." I also understand that Align has identified "a computer program that determines a rate at which each respective dental object will move along its respective route" as the structure that corresponds to this function.

57. In my opinion, the selection of the algorithm or group of algorithms needed to perform the claimed function in question would be readily apparent to a skilled artisan. A skilled artisan would have recognized that "determining a rate" for each dental object required dividing the distance travelled by each dental object by the number of stages in which the dental object moves. A skilled artisan would have arrived at this basic algorithm, which can be expressed as "rate = distance / stage," based on their knowledge and the specification's disclosures. For instance, a skilled artisan would have known that speed is typically expressed as s = d / t, where s is speed, d is distance, and t is time. And a skilled artisan would have recognized, upon reading the specification, however, that the '444 patent expresses the rate at which teeth move in units of "mm/stage." *See, e.g.*, 7:15-16. Thus, a skilled artisan would have concluded that performing the claimed function of determining "rate" requires dividing the distance travelled for a tooth by the number of stages in which it moves.

58. Other disclosures from the '444 patent support my conclusion. For example, claim 20 expresses the same algebraic relationship that identified above by referring to "dividing the total distance for each dental object by its respective maximum speed to determine a number of movement stages." '444 pat., cl. 20. In that scenario, both distance and rate are known but the

number of stages is unknown, and, thus, can be determined by the following equation: stages = distance / rate. A skilled artisan would have recognized, however, that if the number of stages and the distance travelled were known, the same algebraic relationship could be used to compute rate. Indeed, the specification discloses that, in the context of an exemplary "all equal" pattern, the number of stages is an independent variable whereas the rate is a dependent variable: "the rate at which any tooth will move generally depends upon how many total stages are needed to treat the patient . . . ." '444 pat., 6:60-61. These disclosures support my conclusion that a skilled artisan would have recognized that determining rate required dividing distance by the number of stages.

59. I understand that Dr. Xiong contends that the '444 patent does not provide adequate structure corresponding to this function. Xiong Decl., ¶¶ 86-92. I disagree because, as I have expressed, a skilled artisan would have recognized that a computer program using the algorithm of "rate = distance / stage" would practice the claimed function.

60. Additionally, although not mentioned by Dr. Xiong, the fact that the '444 patent also expresses other ways of selecting a rate for each tooth does not change my opinion. For example, the '444 patent describes certain maximum rates at which teeth can travel. *See, e.g.*, '444 pat., 7:15-19, it describes setting a rate based on a patient's pain tolerance, *see, e.g.*, '444 pat., 7:19-21, it describes setting a rate by multiplying the minimum number of stages a tooth needs to move by a maximum rate and dividing that figure by the total number of stages needed for treatment, *see, e.g.*, '444 pat., 7:7:5-11, and it describes slowing the rate at which teeth move during some stages to avoid collisions, *see, e.g.*, '444 pat., 14:9-39. In each of these scenarios, rate can still be determined by rate = distance / stage. Even where a tooth moves at multiple rates during treatment, the rate at which the tooth moves during any particular stage is simply the distance moved in that particular stage in units of mm / stage. In fact, the specification contemplates such

a stage-by-stage determination of rate: as Dr. Xiong acknowledges, the '444 patent recites, "[t]he system user and/or program can suitably select a rate of tooth movement *for each stage*, such as by system user input on a command screen, *or by computer algorithm.*" '444 pat., 7:12-14. Thus, in my opinion, none of the foregoing disclosures change the fact that a skilled artisan would have recognized that a computer program that computed rate by dividing the distance travelled by each tooth by the number of movement stages for that tooth would practice this claim.

61. I understand that Dr. Xiong contends the specification does not disclose adequate corresponding structure for this claim term. Xiong Decl., ¶¶ 86-92. Specifically, Dr. Xiong contends that the specification fails to disclose any algorithm for determining rate. Xiong Decl., ¶¶ 86-92. I disagree with Dr. Xiong's conclusion because, as I have explained, the specification contains sufficient disclosure such that an algorithm would be readily apparent to a skilled artisan.

6. "means for determining a total distance each respective dental object will move" ('444 patent cl. 20)

Align's Construction	Defendants' Construction
a computer program for determining a total distance each respective dental object will move and equivalents E.g., '444 patent, 4:58-5:10	Subject to § 112 ¶ 6 • <u>Function</u>: determining a total distance each respective dental object will move • <u>Structure</u>: None Indefinite

62. I understand that the parties agree that the function corresponding to this term is "determining a total distance each respective dental object will move." I also understand that Align has identified "a computer program for determining a total distance each respective dental object will move and equivalents" as the structure that corresponds to this function.

63. In my opinion, the selection of the algorithm or group of algorithms needed to perform the claimed function in question would be readily apparent to a skilled artisan. In my opinion, a skilled artisan would have recognized that "determining a total distance each respective dental object will move" requires nothing more than summing, for each tooth, the distance travelled by each tooth at each stage. A skilled artisan would have reached this conclusion because the claim refers to "total distance," and summing together numbers is how one determines a "total."

64. I understand that Dr. Xiong contends the specification does not disclose adequate corresponding structure for this claim term. Xiong Decl., ¶¶ 123-128. Specifically, Dr. Xiong contends that the specification fails to disclose any algorithm for determining total distance. Xiong Decl., ¶¶ 123-128. I disagree with Dr. Xiong's conclusion because, as I have explained, the specification contains sufficient disclosure such that an algorithm would be readily apparent to a skilled artisan.

7. "means for adjusting at least one of the route and the rate of at least one dental object to avoid collision with at least one other dental object" ('444 patent cl. 18)

Align's Construction	Defendants' Construction
a computer program that performs collision avoidance via round-tripping, staggering, or slowing, wherein the computer program first attempts staggering of the teeth movement, followed by slowing-down/interim key frames if the staggering does not avoid collisions, and then followed by round-tripping as a last resort and equivalents E.g., '444 patent, 12:41-65	Subject to § 112 ¶ 6 • <u>Function</u>: adjusting at least one of the route and the rate of at least one dental object to avoid collision with at least one other dental object • <u>Structure</u>: None Indefinite

65. I understand that the parties agree that the function corresponding to this term is "adjusting at least one of the route and the rate of at least one dental object to avoid collision with at least one other dental object." I understand that the parties dispute whether the claimed function

requires adjusting *both* the route and the rate of at least one dental object or adjusting *either* the route and the rate of at least one dental object. I have been asked to assume that adjusting *either* of the route and the rate of at least one dental object would practice this claim term.

66. I understand that Align has identified "a computer program that performs collision avoidance via round-tripping, staggering, or slowing, wherein the computer program first attempts staggering of the teeth movement, followed by slowing-down/interim key frames if the staggering does not avoid collisions, and then followed by round-tripping as a last resort and equivalents" as the structure that corresponds to this function. In my opinion, the algorithm recited in Align's proposed construction corresponds to the claimed function. That algorithm appears at column 12, lines 57 through 62 of the '444 patent's specification.

67. A skilled artisan would have recognized that this algorithm corresponds to the claimed function based on disclosures in the '444 patent's specification. The '444 patent states that "in cases where teeth may collide with or obstruct one another during movement, the program is configured to suitably stagger, slow down, and/or plan-round-tripping for the teeth movement." '444 pat., 12:41-44. Thus, a skilled artisan would have recognized that staggering, slowing, and round-tripping were methods of collision avoidance. Moreover, the '444 patent defines each of staggering, slowing, and round-tripping as methods that adjust either the route, the rate, or both. According to the '444 patent, "[s]taggering" delays a tooth from moving when it otherwise would move and thus changes the rate at which a tooth moves during at least one stage to 0mm/stage, *e.g.*, from .25mm/stage or another rate. '444 pat., 12:44-48. "Slowing" means a tooth moves slower than other teeth or even stops. '444 pat., 12:48-51. And "Round-tripping" impacts both route and rate because it requires moving "moving a first tooth out of the path of a second tooth, and once the second tooth has moved sufficiently, moving the first tooth back to its previous

position before proceeding to a desired final position." '444 pat., 12:51-55. Thus, in my opinion, a skilled artisan would have recognized that the algorithm recited in Align's proposed construction corresponds to the claimed function of "adjusting at least one of the route and the rate of at least one dental object to avoid collision with at least one other dental object."

68. I understand that Dr. Xiong contends that the '444 patent does not disclose sufficient corresponding structure for the claimed function. Xiong Decl., ¶¶ 107-115. According to Dr. Xiong's discussion of the corresponding algorithm in paragraph 112 of his report, attempting staggering, slowing, and then round-tripping is not an algorithm because "the specification . . . does not disclose anything about how to configure the required computer program, much less describe how to perform staggering, slowing down, or round-tripping—e.g., how long to stagger the movement of a tooth, how much to slow down the movement of a tooth, how much to change the route of a tooth." Xiong Decl., ¶ 112.

69. I disagree with Dr. Xiong's conclusion. As I have already explained, a skilled artisan would have recognized that attempting staggering, slowing, and then round-tripping corresponds to the claimed function. Moreover, the specification does describe how to perform each of staggering, slowing, and round-tripping at column 12, lines 44-55. '444 pat., 12:44-55. In my opinion, and regardless of whether the specification states exactly how long to stagger, how much to slow, and to what extent to round-trip, these disclosures adequately convey that software that attempts staggering, slowing, and then round-tripping would practice this claim term.

8. "means for determining an optimal number of stages for the order of movement of the dental objects" ('444 patent cls. 19-20)

Align's Construction	Defendants' Construction
a computer program that determines an optimal number of stages by selecting the largest number of the minimum number of stages	Subject to § 112 ¶ 6

needed to place the dental objects in their final, desired positions and equivalents E.g., '444 patent, 15:6-20	• Function: determining an optimal number of stages for the order of movement of the dental objects • Structure: None Indefinite

70. I understand that the parties agree that the function corresponding to this term is "determining an optimal number of stages for the order of movement of the dental objects." I also understand that Align has identified "a computer program that determines an optimal number of stages by selecting the largest number of the minimum number of stages needed to place the dental objects in their final, desired positions and equivalents" as the structure that corresponds to this function.

71. In my opinion, "a computer program that determines an optimal number of stages by selecting the largest number of the minimum number of stages needed to place the dental objects in their final, desired positions and equivalents" corresponds to the claimed function. The '444 patent states that, "in an exemplary embodiment, the optimum number of stages is the largest number of the minimum stages needed to place the patient's teeth in their final, desired position." '444 pat., 15:9-12. It also provides an example of how to apply this algorithm:

> For example, a patient has three teeth that need to be moved during treatment, wherein the first tooth needs 4 stages to move to its final position, the second tooth needs 9 stages to move to its final position, and the third tooth needs 6 stages to move to its final position. Assuming each of these teeth is scheduled to begin moving at the same stage, the optimum number of stages is 9 since this is the minimum number of stages needed to place all of the teeth in their final position.

'444 pat., 15:12-20. From these disclosures, a skilled artisan would have recognized that the algorithm recited in Align's proposed construction corresponds to the claimed function.

72. I understand that Dr. Xiong contends that the '444 patent does not disclose sufficient corresponding structure because it "does not describe how the computer program is to

determine the 'minimum of stages' for a particular tooth." Xiong Decl. ¶¶ 117-121. In essence, Dr. Xiong's objection is that the specification does not disclose how to calculate the "minimum number of stages" for each tooth and, thus, it does not disclose how to accomplish the claimed function. I disagree with Dr. Xiong's conclusion. In my opinion, a skilled artisan would have recognized that, regardless of how the minimum number of stages is determined for each tooth, a computer program that selects the largest number of minimum stages would practice this claim term.

73. I also disagree with Dr. Xiong's statement that "there is no objective method by which computer scientists or programmers could write software to determine 'an optimal number of stages for the order of movement of the dental objects." Xiong Decl., ¶116, n.3. Selecting the largest number of minimum stages, as the '444 patent instructs, is an objective method of determining an "optimal number of stages."

9. "means for ordering the movement of the dental objects in a V-shaped pattern" ('444 patent cl. 22)

Align's Construction	Defendants' Construction
a computer program configured to utilize the pattern depicted in Figure 5 and equivalents E.g., '444 patent, 9:12-15, 9:42-44, Fig. 5	Subject to § 112 ¶ 6 • Function: ordering the movement of the dental objects in a V-shaped pattern • Structure: None Indefinite

74. I understand that the parties agree that the function corresponding to this term is "ordering the movement of the dental objects in a V-shaped pattern." I also understand that Align has identified "a computer program configured to utilize the pattern depicted in Figure 5 and equivalents" as the structure that corresponds to this function. Figure 5 is reproduced below:

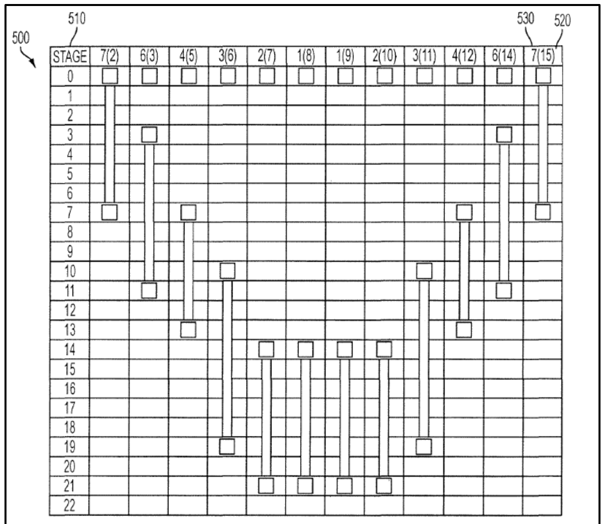

FIG. 5

75. In my opinion, a "computer program configured to utilize the pattern depicted in Figure 5 and equivalents" corresponds to the claimed function. In Figure 5, the y-axis denotes the treatment "stage" and the x-axis denotes the identity of each respective tooth using "the standard teeth numbering system 520." '444 patent, 10:45-49. Figure 5 thus indicates at which stage each tooth moves via rectangles bounded on either end with squares. For example, according to Figure 5's algorithm, tooth 7(2) moves beginning at stage 0 and ending at stage 7 while tooth 6(3) moves beginning at stage 3 and ending at stage 11. The overall pattern of movement created by the algorithm, as is apparent from the figure itself, is in the shape of a "V." *Id.*

76. I understand that Dr. Xiong contends that the '444 patent does not disclose sufficient corresponding structure for the claimed function. Xiong Decl. ¶¶ 169-78. I disagree. As I have explained above, Figure 5 conveys to a skilled artisan when to start and end the movement of teeth to achieve a "V" pattern. Thus, Dr. Xiong's assessment that "[t]his figure provides no information about an algorithm," "does not provide any information about how the computer program is programmed to perform the function," and does not "describe what the particular V-shaped pattern should look like . . ." is incorrect. Xiong Decl., ¶ 176. Moreover, the

other passages that Dr. Xiong criticizes, Xiong Decl., ¶¶ 170 (quoting ’444 pat., 9:12-15), 173 (quoting ’444 pat., 9:42-44), indicate to a skilled artisan that Figure 5 is a “V-shaped” and that a program can be “configured to utilize” such a pattern. In sum, a skilled artisan would have recognized that Figure 5 corresponds to the claimed function of ordering the movement of dental objects in a V-shaped pattern.

10. “means for round tripping at least one dental object” (’444 patent cl. 27)

Align’s Construction	Defendants’ Construction
a computer program configured to move a first tooth out of the path of a second tooth, and once the second tooth has moved sufficiently, move the first tooth back to its previous position before proceeding to a desired final position of the first tooth and equivalents E.g., ’444 patent, 12:51-55	Subject to § 112 ¶ 6 • <u>Function</u>: round tripping at least one dental object • <u>Structure</u>: None Indefinite

77. I understand that the parties agree that the function corresponding to this term is “round tripping at least one dental object.” I also understand that Align has identified “a computer program configured to move a first tooth out of the path of a second tooth, and once the second tooth has moved sufficiently, move the first tooth back to its previous position before proceeding to a desired final position of the first tooth and equivalents” as the structure that corresponds to this function.

78. In my opinion, “a computer program configured to move a first tooth out of the path of a second tooth, and once the second tooth has moved sufficiently, move the first tooth back to its previous position before proceeding to a desired final position of the first tooth and equivalents” corresponds to the claimed function of round-tripping at least one dental object. A skilled artisan would have recognized as much because the algorithm recited in Align’s proposed construction is how the ’444 patent defines round-tripping. *See e.g.*, ’444 patent, 12:51-55.

79. I understand that Dr. Xiong contends that the ’444 patent does not disclose adequate corresponding structure because the “passage only provides a definition for ‘round tripping’” and “it does not provide an algorithm or otherwise explain how the computer is to be configured to perform the function of ‘round tripping at least one dental object.’” Xiong Decl. ¶¶ 218-21. I disagree with Dr. Xiong’s conclusion because a skilled artisan would have recognized that the ’444 patent’s definition of round-tripping is, itself, an algorithm for performing round-tripping.

D. Additional Terms in ClearCorrect’s Appendix A

80. I understand that, beyond the terms I discuss above, Dr. Xiong has offered opinions regarding the following claim terms:

- “means for receiving an electronic representation of a desired final position for each respective dental object”;
- “means for determining the distance each respective dental object will move to achieve its respective final position”;
- “means for dividing the total distance for each dental object by its respective maximum speed to determine a number of movement stages for each dental object”;
- “means for determining a number of non-movement stages for each respective dental object”;
- “means for adding the number of movement stages to the number of non-movement stages for each dental object to determine a minimum number of stages for each respective dental object”;
- “means for selecting the largest of the minimum number of stages”;
- “means for ordering the movement of the dental objects in an all-equal pattern”;
- “means for ordering the movement of the dental objects in an A-shaped pattern”;
- “means for ordering the movement of the dental objects to form an M-shaped pattern”;
- “means for ordering the movement of the dental objects in a mid-line shift pattern”;
- “means for staggering the movement of at least two dental objects”; and

- "means for slowing the movement of at least one dental object."

See Xiong Decl., ¶¶ 46-50, 79-84, 129-135, 136-142, 143-149, 150-156, 157-167, 179-189, 190-200, 201-211, 212-216, 222-226. I also understand, however, that the Court prohibited ClearCorrect from submitting argument regarding these additional terms and that, as a result, how each term should be construed is not at issue in this lawsuit. At this time, I have not been asked to consider these additional terms and I have not done so.

V. RIGHT TO SUPPLEMENT

81. I reserve the right to modify or supplement the opinions I have expressed herein. In particular, if the Court later allows ClearCorrect to make arguments regarding the additional terms identified above in paragraph 80, above, I may later form and offer opinions about them.

VI. MATERIALS CONSIDERED

82. In forming my opinions set forth herein, I have considered and relied upon my education, knowledge of the relevant fields, and experience. I also have considered the following materials: U.S. Patent Nos. 8,038,444, 10,456,217, 10,524,879, and 11,369,456; the file histories for U.S. Patent Nos. 8,038,444, 10,456,217, 10,524,879, 11,369,456, 11,717,381, 10,402,631, 9,326,830, 11,950,777; the file history for U.S. Patent Application No. 18/481,798; U.S. Provisional Patent Application Nos. 60/824,022 and 60/824,024, the October 31, 2024, Declarations of Zixiang Xiong, Ph.D. and William Harrell Jr., DMD; and ClearCorrect's Opening Claim Construction brief in this proceeding (ECF No. 121).

83. If called to testify or to give additional opinions regarding this matter, I reserve the right to rely upon any additional information or materials that may be provided to me or that are relied upon by any of ClearCorrect's experts or witnesses.

Dated: November 22, 2024

Karan Singh, Ph.D.

APPENDIX A

Karan Sher Singh

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Bio and Career Highlights

Karan Singh is an expert in Computer Graphics and Human Computer Interaction, and a Professor in Computer Science (since 2002) at the University of Toronto. Born and raised in India, he has lived and worked in many parts of the world including Canada, China, France, India, Japan, New Zealand, Singapore, and U.S.A. He holds a BTech. (1991), MS (1992), and PhD (1995) in Computer Science and Engineering. His research interests lie at the intersection of art, Artificial Intelligence (AI), Computer Graphics (CG) and Human Computer Interaction (HCI): spanning interactive modeling and animation, visual perception, visualization, sketch/touch and interfaces for the web and Augmented/Virtual Reality. Karan has been a development lead on the technical Oscar (2003) winning modeling and animation system *Maya*. He has co-founded multiple companies including sketch2/FindSpace (acquired by MRI Software 2021), JanusVR, conceptualiz, and JALI Research, and supervised the design and research of critically acclaimed research systems ILoveSketch, MeshMixer (acquired by Autodesk in 2011), and FlatFab. Karan co-directs a globally reputed graphics and HCI lab, DGP, has over 150 peer-reviewed publications, and has supervised over 50 MS/PhD/ postdoctoral students. He was the R&D Director for the 2005 Oscar winning animated short film *Ryan* and has had an exhibition of electronic art titled Labyrinths. He was awarded a University of Toronto President's Impact Award in 2018 for contributions in computer graphics, design and animation, and an IIT-Madras Distinguished Alumni Award in 2024. His research on audio-driven facial animation *JALI*, has been used to animate speech for characters in major AAA games like *Cyberpunk 2077* and *Call of Duty: Modern Warfare2*. His work on anatomically animated faces *Animatomy*, was one of the important technical advances in the film *Avatar: the way of water*, for which it was awarded the Oscar for the best Visual Effects 2023. He is an affiliate of the BMO lab for creative research in Art and Performance, the Vector Institute for AI, and has recently taken over leadership of the School of Cities India to focus on urban problems relating to people and our planet.

Degrees

- Ph.D., *Computer and Information Science*. Ohio State University. 12/92-10/95
  Thesis: Realistic Human figure Synthesis and Animation for VR applications.
- M.S., *Computer and Information Science.* Ohio State University. 09/91-11/92
- B.Tech., *Computer Science and Engineering*. IIT Madras, India. 08/87-07/91

Employment

- Jul 2002- present: *Professor*, Computer Science, University of Toronto, Canada.
- Jan 2024 - present: *Associate Director*, School of Cities India, University of Toronto, Canada.
- Jan 2020-present: *Academic researcher*, Weta Digital https://www.wetafx.co.nz
- Jul 2017-present: *Co-Founder*, JALI Inc. www.jaliresearch.com
- Dec 2014-2020: *Co-Founder*, JanusVR www.janusvr.com (open source)
- Jul 2014-2018: *Co-Founder*, FlatFab www.flatfab.com (open source)
- Jan 2006- May 2021: *Co-Founder*, Sketch2, (acquired by MRI software).
- Jun 1999- Jun 2001: *Technical Lead*, Paraform Inc., Santa Jose, CA.
- Dec 1995- Jan.1999: *Graphics Researcher,* Alias Inc., Toronto, Canada.
- Jan 1994- Dec 1994: *Invited researcher,* Communication Systems Research Labs, Advanced Telecommunications Research (ATR), Kyoto, Japan.
- Apr 1994- Nov 1994: *Bartender*, Taberuna Matano, Nara, Japan.

Visiting Professorships

- Winter 2020, Victoria University, New Zealand.
- Winter 2013, NUS Singapore.
- Summer 2011, INRIA Rhone-Alpes.
- Summer 2009, INRIA Sophiantipolis.
- Aug. 2008 – March 2009, Computer Science, Indian Inst. of Tech. (IIT) Delhi.
- Summer 2008, Microsoft Research, Beijing.
- Winter 2007, Computer Science, University of Pennsylvania.
- Summer 2005, Computer Science, University of Texas, Austin.
- Feb.1999- May 1999: Computer Science, University of Otago, New Zealand.
- Summer 1989-1993: *Student*, *Counselor*, *Instructor*, The Ross Program (Number Theory & Combinatorics).

Selected Honours and awards

- *IIT Madras Distinguished Alumni Award*, 2024. https://acr.iitm.ac.in/latestdaas/prof-karan-sher-singh/
- ***Avatar: the way of water*, **Oscar VFX, 2023 (Facial animation R+D).
- *University of Toronto, President's Impact Award, 2018* https://research.utoronto.ca/honours-awards/presidents-impact-award-academy
- *Canadian Human Computer Communications Society*, *Lifetime Achievement Award*, May 2019. http://graphicsinterface.org/awards/chccs-scdhm-achievement/karan-singh/
- *University of Toronto Inventor of the year Award 2015.*
- *MITACS* 2008-2009 Mentorship Award of Excellence.
- *Indo-Canada Chamber of Commerce* (Technology Award), 2008.
- ***Ryan*.** (Software R&D Director) **Oscar** (Best Animated Short) 2005, *Cannes* 2004, Kodak Discovery, Young Critic's Prize, Canal+ Best Film, *SIGGRAPH* 2004, Los Angeles, CA, Electronic Theater, Jury Prize, *Annecey* International Film Festival 2004, Jury Award, *Prix Arts Electronica* 2004, Golden Nica, *Ottawa* animation festival, Grand Prize, *Genie* (Best Canadian Animation) 2005.
- ***Maya 1.0, 1998.*** **(Technical Oscar 2003,** only 38 such awards since 1930**)** for R&D work on character and facial animation tools that is now the de facto commercial standard in modeling and animation.

Litigation Consulting (testifying expert)

- Maxell (Mayer Brown, No. 5:23-cv-00092-RWS).
- Align (Bartlit Beck, C.A. No. 6:20-cv-00979).
- Align (Bartlit Beck, C.A. No. 18-886-LPS).
- Align (Paul Hastings, C.A. No. 17-1647-LPS, C.A. No. 18-886-LPS).
- Apple (Gibson Dunn NDCAL 12-cv-00630-LHK).
- Apple (Morrison Foerster ITC 337-TA-796, NDCAL Case No. 11-cv-01846 LHK).
- PARTEQ Research and Development (Susman Godfrey No. 2:I4-cv-53 E.D. Tex.).
- Leapfrog (Morrison Foerster C.A. No. 14-261-RGA).

Selected Patents (25 in total)

1. System and method for generation of an interactive color workspace M Shugrina, W Zhang, F Chevalier, S Fidler, K Singh, US Patent 11,263,791, 2022.
2. System and method for animated lip synchronization P Edwards, C Landreth, E Fiume, K Singh, US Patent 10,839,825, 2020.
3. Method and system for linking a first virtual reality (VR) immersive space with a second VR immersive space. James McCrae, Karan Singh. (US pat. 10,593,105, 2020).
4. Interactive labyrinth curve generation and applications H. Pedersen, K. Singh (US pat. no. 7928983), 2006.
5. Method and apparatus for geometric model deformation using wires K. Singh (U.S. patent no. 6,204,860) 1999.

Selected Keynotes, Invited Lectures and Colloquia ACM Distinguished Speaker 2017-2020

- *Expressive Facial Modeling and Animation.* Keynote: ACM Symposium on Computer Animation SCA, Aug. 2024.
- *High performance Interfaces for Modeling and Animation* Keynote: (ACM/EG High Performance Graphics 21)
- *Expressive Facial Modeling and Animation.* Keynote: ACM Motion in Games, Nov. 2019.
- *…On Creative Visual Communication.* Keynote, SIBGRAPI, SIBGAMES 2018.
- *The immersive internet:* colloquium *VRTO, LSI 2017, SIGGRAPH 2017, SIGGRAPH asia 2017.*
- *Making Faces.* Distinguished Lecture: Animafest Zagreb, June 13, 2015.
- *The future of internet interaction.* Meet the Media Guru, Future ways of living, Milan, June 11, 2015.
- *Perception, Drawing and Interactive Modeling.* College de France June 8, 2015. *http://www.college-de-france.fr/site/marie-paule-cani/symposium-2015-06-08-11h45.htm*
- *Psychorealism, anatomy and animation,* Chinese International film festival, Hangzhou April 2007.
- *Art and science of computational anatomic modeling,* Ontario Science Center, Nov. 2005.
- *Labyrinths and Mazes,* INRIA Grenoble June 2005, Ross Program 2005.

Selected Publications (last 10 years, 150+ in total) http://www.dgp.toronto.edu/~karan/pubs.htm

- [PAS24] *S^3: Speech, Script and Scene driven Head and Eye Animation,* Y. Pan, R. Agrawal, K. Singh, *ACM Transactions on Graphics (TOG), presented at SIGGRAPH 2024* (12 pages).
- [Y+24] *3D-Layers: Bringing Layer-Based Color Editing to VR Painting.* E. Yu, F. Chevalier, K. Singh, A. Bousseau. *ACM Transactions on Graphics (TOG), presented at SIGGRAPH 2024* (15 pages).
- [N+24] *Surface-Filling Curve Flows via Implicit Medial Axes.* Y. Noma, S. Sellan, N. Sharp, K. Singh, A. Jacobson. *ACM Transactions on Graphics (TOG), presented at SIGGRAPH 2024* (11 pages).
- [P+24] *Diffusion Handles: Enabling 3D Edits for Diffusion Models by Lifting Activations to 3D*. K Pandey, P Guerrero, M Gadelha, Y Hold-Geoffroy, K. Singh, N. Mitra. *Highlight IEEE CVPR 2024.* (13 pages)
- [Y+24ii] *ProInterAR: A Visual Programming Platform for Creating Immersive AR Interactions.* H. Ye, J. Leng, P. Xu, K. Singh, H. Fu, *ACM CHI 2024* (15 pages).
- [F+23] *MAGIC: Manipulating Avatars and Gestures to Improve Remote Collaboration*. Catarina Fidalgo, Mauricio Sousa, Daniel Mendes, Rafael dos Anjos, Daniel Medeiros, Karan Singh, and Joaquim Jorge. *IEEE Conference on Virtual Reality and 3D User Interfaces (IEEE VR), 2023*.
- [PCS23] *Juxtaform: interactive visual summarization for exploratory shape design,* K. Pandey, F. Chevalier, K Singh. *ACM Transactions on Graphics (TOG), to be presented at SIGGRAPH 2023* (14 pages).
- [C+22] *Animatomy: an Animator-centric, Anatomically Inspired System for 3D Facial Modeling, Animation and Transfer.* B. Choi, H. Eom, B. Mouscadet, S. Cullingford, K. Ma, S. Gassel, S. Kim, A. Moffat, M. Maier, M. Revelant, J. Letteri, K. Singh. *ACM Transactions on Graphics (TOG), presented at SIGGRAPH Asia 2022* (9+14 pages).
- [P+22] *Animatomy: an Animator-centric, Anatomically Inspired System for 3D Facial Modeling, Animation and Transfer* Y. Pan, C. Landreth, E. Fiume, K. Singh. *ACM Transactions on Graphics (TOG), presented at SIGGRAPH Asia 2022* (9 pages).
- [PBS22] *Face Extrusion Quadmeshes.* K. Pandey, J Baerentzen, K Singh. *ACM Transactions on Graphics (TOG), presented at SIGGRAPH 2022* (9 pages).
- [Y+22] *Piecewise-Smooth Surface Fitting onto Unstructured 3D Sketches*. E Yu, R Arora, J Baerentzen, K Singh, A Bousseau *ACM Transactions on Graphics (TOG), presented at SIGGRAPH 2022* (17 pages).
- [CSG21] *PosterChild: Blend-Aware Artistic Posterization.* CKT Chao, K Singh, Y Gingold. Computer Graphics Forum 40 (4), 87-99. (13 pages).
- [AS21] *Mid-Air Drawing of Curves on 3D Surfaces in Virtual Reality.* R. Arora and K. Singh. *ACM Transactions on Graphics (TOG), presented at SIGGRAPH 2021* (17 pages).
- [KS21] *Optimizing UI Layouts for Deformable Face-Rig Manipulation.* J. Kim and K. Singh. *ACM Transactions on Graphics (TOG), SIGGRAPH 2021* (12 pages).
- [A+21] *Interactive Modelling of Volumetric Musculoskeletal Anatomy*. R. Abdrashitov, S. Bang, D. Levin, A. Jacobson, K. Singh. *ACM Transactions on Graphics (TOG), SIGGRAPH 2021* (13 pages).
- [K+21] *Levitating Rigid Objects with Hidden Rods and Wires.* S. Kushner, R. Ulinski, K. Singh, D. Levin, A. Jacobson, *Computer Graphics Forum CGF, Eurographics 2021.* R. (12 pages).
- [B+21] *Space, Time, and Choice: A Unified Approach to Flexible Personal Scheduling*. V Bilbily, E Huynh, K Singh,

F Chevalier. The 34th Annual ACM Symposium on User Interface Software and Technology, ACM UIST, 484-497 (14 pages).

- [DSG21] *SurgeonAssist-Net: Towards Context-Aware Head-Mounted Display-Based Augmented Reality for Surgical Guidance*. M Doughty, K Singh, NR Ghugre. International Conference on Medical Image Computing and Computer-Assisted Intervention (ACM MICCAI 21). (11 pages).
- [Y+21] *CASSIE: Curve and Surface Sketching in Immersive Environments*. E Yu, R Arora, T Stanko, J Baerentzen, K Singh, A Bousseau. In Proceedings of the CHI Conference on Human Factors in Computing Systems (ACM CHI 2021) (14 pages).
- [PCS21] *Color by Numbers: Interactive Structuring and Vectorization of Sketch Imagery*. A.D. Parakkat, M.P. Cani, K. Singh. In Proceedings of the CHI Conference on Human Factors in Computing Systems (ACM CHI 2021) (11 pages).
- [X+20] *RigNet: Neural Rigging for Articulated Characters.* Z Xu, Y Zhou, E Kalogerakis, C Landreth, K Singh. *ACM Transactions on Graphics 2020 (SIGGRAPH)* (14 pages).
- [S+20] *Nonlinear Color Triads for Approximation, Learning, and Direct Manipulation of Color Distributions.* M. Shugrina, A. Kar, S. Fidler, K. Singh. *ACM Transactions on Graphics 2020 (SIGGRAPH)* (14 pages).
- [ACS20] *Interactive Exploration and Refinement of Facial Expression using Manifold Learning*. R. Abdrashitov, F. Chevalier, K. Singh ACM UIST 2020. (10 pages).
- [BFS19] *Signifier-Based Immersive and Interactive 3D Modeling*. A Bærentzen, JR Frisvad, K Singh, 25th ACM Symposium on Virtual Reality Software and Technology, *(ACM VRST, 2019)*.
- [A+19] *MagicalHands: Mid-Air Hand Gestures for Animating in VR.* R Arora, RH Kazi, DM Kaufman, W Li, K Singh. (*ACM UIST 2019)* (10 pages).
- [X+19] Predicting Animation Skeletons for 3D Articulated Models via Volumetric Nets. Z Xu, Y Zhou, E Kalogerakis, K Singh. *2019 International Conference on 3D Vision (3DV)*. (10 pages).
- [A+19ii] *Volumetric Michell trusses for parametric design & fabrication* R Arora, A Jacobson, TR Langlois, Y Huang, C Mueller, W Matusik, W. Matusik, A. Shamir, K. Singh, D. Levin. Proceedings of the ACM Symposium on Computational Fabrication, (*ACM SCF 2019*) (13 pages).
- [S+19ii] *Creative Flow+ Dataset.* M. Shugrina, S. Fidler, K. Singh. Computer Vision and Pattern Recognition (IEEE CVPR) 2019.
- [S+19] *Color Builder: a Direct Manipulation Interface for Versatile Color Theme Authoring.* M. Shugrina, W. Zhang, F. Chevalier, S. Fidler, K. Singh. In Proceedings of the CHI Conference on Human Factors in Computing Systems (ACM CHI '19).
- [L+19] *HoloDoc: Enabling Mixed Reality Workspaces that Harness Physical and Digital Content.* Z. Li, M. Annett, K. Hinckley, K. Singh and D. Wigdor. In Proceedings of the CHI Conference on Human Factors in Computing Systems (ACM CHI '19).
- [AJS19] *A system for efficient 3D printed stop-motion face animation,* R. Abdrashitov, A. Jacobson, K. Singh. *ACM Transactions on Graphics 2019 (SIGGRAPH)* (12 pages).
- [X+18] *Model-Guided 3D Sketching*, P Xu, H Fu, Y Zheng, K Singh, H Huang, CL Tai, *IEEE Transactions on Visualization and Computer Graphics 2018.* (13 pages).
- [Z+18] *VisemeNet: Audio-Driven Animator-Centric Speech Animation.* Y. Zhou, C. Landreth, E. Kalogerakis, K. Singh. *ACM Transactions on Graphics 2018 (SIGGRAPH 2018*).
- [A+18] *SymbiosisSketch: Combining 2D & 3D Sketching for Designing Detailed 3D Objects in Situ.* R. Arora, R. Habib, T. Grossman, K. Singh, and G. Fitzmaurice. Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems 2018 (12 pages).
- [WS17] *Bend-a-rule: a fabrication-based workflow for 3D planar contour acquisition*. M. Wei, K. Singh. *Proceedings of ACM Syposium on Computational Fabrication SCF 2017,* (8 pages).
- [S+17] *Participatory Shelter Design for Displaced Populace: Reflections from a User Study.* S. Sabie, S. Easterbrook, C. Munteanu, K. Singh, O. St-Cyr, F. Hashim. HCI across Borders Symposium 2017. (7 pages)
- [A+17ii] *Experimental Evaluation of Sketching on Surfaces in VR.* R. Arora, R. Habib, F. Anderson, T. Grossman, K. Singh, and G. Fitzmaurice. Proceedings of the ACM SIGCHI Comference on Human Factors in Computing Systems 2017 (12 pages).
- [A+17] *SketchSoup: Exploratory Ideation using Design Sketches.* R. Arora, I. Darolia, V. P. Namboodiri, K. Singh and A. Bousseau, *Computer Graphics Forum, CGF 2016* (11 pages).
- [E+16] *JALI: An Animator-Centric Viseme Model for Expressive Lip-Synchronization.* P. Edwards, C. Landreth, E. Fiume, K. Singh. *ACM Transactions on Graphics 2016* (SIGGRAPH 2016) (11 pages).

- [X+16] *Using Isophotes and Shadows to Interactively Model Normal and Height Fields*. Q Xu, S Liu, Y Gingold, K Singh. Computers & Graphics 2016 (13 pages).
- [WSK16] *Foreshortening produces errors in the perception of angles pictured as on the ground*. M Wnuczko, K Singh, JM Kennedy *Attention, Perception, & Psychophysics 78 (1), 309-316, 2016* (8 pages).
- [H+16ii] *Multi-Device Storyboards for Cinematic Narratives in VR*. R. Henrikson, B. Araujo, F. Chevalier, K. Singh, R. Balakrishnan (ACM UIST 2016) (11 pages).
- [LS16] *Gestural Motion Editing using Mobile Devices.* N. Lockwood, K. Singh. (ACM Motion in Games 2016) (6 pages).
- [H+16] *Storeoboard: Sketching Stereoscopic Storyboards.* R. Henderson, B. Araujo, F. Chevalier, K.Singh, R. Balakrishnan. *Proceedings of the SIGCHI conference on Human Factors in computing systems* (CHI '16). (12 pages).
  [A+16] *Snake Charmer: Physically Enabling Virtual Objects.* B Araujo, R Jota, V Perumal, JX Yao, K Singh, D Wigdor. Proceedings of the TEI'16: Tenth International Conference on Tangible Embedded, and Embodied Interaction. (9 pages).
- [dPS15] *SecondSkin: Sketch-based Construction of Layered 3D Models.* C. de Paoli, K. Singh. *ACM Transactions on Graphics 2015* (SIGGRAPH 2015) (10 pages).
- [B+15] *Modeling Character Canvases from Cartoon Drawing.* M. Bessmeltsev, W. Chang, A. Sheffer, K. Singh. *ACM Transactions on Graphics 2015* (SIGGRAPH 2015) (14 pages).
- [C+15] *ColorBless: Augmenting Visual Information for Colorblind People with Binocular Luster Effect.* S. Chua, H. Zhang, M. Hammad, S. Zhao, S. Goyal, K. Singh. *ACM Transactions on Computer-Human Interaction (TOCHI), 21, 6 (January 2015), Article 32, (presented at CHI'15)* (20 pages)
- [XGS 15] *Inverse Toon Shading: Interactive Normal Field Modeling with Isophotes*. Q. Xu, Y. Gingold, K. Singh. SBIM, Expressive 2015 Best Paper Award.
- [X+14] *True2Form: 3D Curve Networks from 2D Sketches via Selective Regularization.* B. Xu, W. Chang, A. Sheffer, A. Bousseau, J. McCrae, K. Singh. *ACM Transactions on Graphics 2014 (presented at* SIGGRAPH 2014). (13 pages).
- [BAS14] *Interactive Shape Modeling using a Skeleton-Mesh Co-Representation.* A. Baerentzen, R. Abdrashitov, K. Singh. *ACM Transactions on Graphics 2014 (presented at* SIGGRAPH 2014). (10 pages).
- [SS14] *Flow complex based shape reconstruction from 3D curves.* B. Sadri, K. Singh. *ACM Transactions on Graphics 2014 (presented at* SIGGRAPH 2014). (15 pages).
- [X+14ii] *Zero-latency tapping: using hover information to predict touch locations and eliminate touchdown latency*. H. Xia, R. Jota, B. McCanny, Z. Yu, C. Forlines, K. Singh, and D. Wigdor. *Proceedings of the 2014 symposium on User Interface Software and Technology* (ACM UIST). (9 pages).
- [MUS14] *FlatFitFab: Interactive Modeling with Planar Sections*. J. McCrae, N. Umetani, K. Singh *Proceedings of the 2014 symposium on User Interface Software and Technology* (ACM UIST). (10 pages).
- [A+14] *Mosaic: Sketch-Based Interface for Creating Digital Decorative Mosaics*. R. Abdrashitov, E. Guy, J. Yao, K. Singh. *Expressive: Sketch-Based Interfaces and Modeling, 2014.* Best paper Award.
- [F+14] *LACES: Live Authoring Through Compositing and Editing of Video Stream*. D. Freeman, S. Santosa, F. Chevalier, R. Balakrishnan and K. Singh *Proceedings of the SIGCHI conference on Human Factors in computing systems* (CHI '14). April 2014.

Selected Teaching (43 undergraduate courses, 16 graduate courses at U of Toronto)

- CSC 317 Computer Graphics.
- CSC 373 Algorithm Design, Analysis and Complexity.
- CSC 199 The Natural world and computer graphics.
- CSC 148 Introduction to Computer Science.
- CSC 490 Capstone Design Course: Stroke, touch and mobile interaction
- CSC 491 Capstone Design Course: Interactive Graphics.
- CSC 2529 Character Animation.
- CSC 2505 Geometric Modeling.
- CSC 2521 Topics in HCI/Graphics: Sketch interaction, perception and modeling.
- CSC 2521 Interactive 3D modeling for design and fabrication.
- CSC 2524 Topics in Interactive Computing AR/VR.
- CSC 2529 Facial animation.